Effect of β-Adrenergic Receptor Blockade on Atrial Natriuretic Peptide in Essential Hypertension

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SUMMARY Plasma levels of atrial natriuretic peptide (ANP) were measured in 32 untreated subjects with essential hypertension and in 31 patients undergoing long-term treatment with β-blockers. Patients receiving β-blockers had significantly higher mean plasma ANP levels (72.0 ± 36.0 [SD] pg/ml) than did untreated hypertensive subjects (39.8 ± 15.8 pg/ml; p<0.01) and healthy normotensive controls (33.9 ± 16.6 pg/ml; n = 61, p<0.01), while the mean plasma ANP concentration in untreated hypertensive subjects was not statistically different from that in control subjects. Administration of atenolol, 50 mg/day, for 4 weeks to 10 untreated subjects resulted in a significant (p<0.001) rise in plasma ANP levels (from 38.8 ± 9.5 to 68.7 ± 20.6 pg/ml). In 31 patients undergoing long-term treatment with β-blockers, multivariate regression analysis revealed that age, pretreatment mean blood pressure, and plasma concentration of cyclic 3',5'-guanosine monophosphate (cGMP) were significant predictors of plasma ANP levels. These results suggest that β-adrenergic receptor blockade in patients with essential hypertension elevates plasma ANP levels with a concomitant rise in cGMP concentrations, and that increased ANP in plasma may play a role in the compensatory mechanism that operates in response to β-adrenergic receptor blockade.

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KEY WORDS • atrial natriuretic peptide • atrial natriuretic factor • essential hypertension • β-adrenergic blockade • cyclic GMP • catecholamines

A growing body of evidence now indicates that atrial natriuretic peptide (ANP) is a circulating hormone in humans. Plasma levels of ANP increase in patients with various pathological conditions, including paroxysmal atrial arrhythmias, congestive heart failure, chronic renal failure, and primary aldosteronism. Although a few reports suggest that plasma ANP levels are elevated in patients with essential hypertension (EH), whether high blood pressure per se is responsible for elevated plasma ANP levels is unknown. To our knowledge, posttreatment changes in plasma ANP levels in EH patients have not been examined. In the course of such a study, we incidentally found that some EH patients showed an increase in plasma ANP levels after treatment and that these patients had received β-blockers. In the present article, we report the effect of β-blockers on plasma ANP levels in EH patients.

Subjects and Methods

Subjects
Thirty-one EH patients undergoing long-term treatment with β-blockers (treatment range, 1–40 months; mean treatment time, 13.8 months) were studied (Table 1). Twenty-five of the patients had received 50 or 100 mg of atenolol daily, and the remaining six had received 200 mg of acebutolol daily. Thirty-two age-matched untreated subjects with EH and 61 age-matched normotensive healthy subjects served as controls (see Table 1). The diagnosis of EH was made after exclusion of secondary hypertension by routine examinations, including plasma renin activity and aldosterone determinations. Renal arteriography or ad-
The coefficients of variation averaged 3.9% for intra-assay error and 11.1% for interassay error. Atenolol or acebutolol in an amount of 50 mg/day was administered to some subjects with untreated EH. The mean pretreatment blood pressure in patients receiving β-blockers was not significantly different from that in untreated EH subjects (see Table 1). Normotensive healthy subjects consisted of medical staff and healthy subjects seeking a medical checkup in the Hospital of the Institute for Adult Diseases, Asahi Life Foundation.

In 10 untreated EH subjects (9 men and 1 woman), changes in plasma ANP levels were examined after treatment with atenolol, 50 mg/day, for 4 weeks. Mean blood pressure was decreased significantly (p < 0.001) by this treatment (from 122.7 ± 6.7 to 102.1 ± 9.5 [SD] mm Hg).

Blood samples were collected by venipuncture into heparinized tubes from subjects in the upright position. The subjects were kept in the sitting position for 30 minutes before blood sampling. When plasma levels of cyclic guanosine 3',5'-monophosphate (cGMP) and catecholamines were measured, ethylenediaminetetraacetic acid 2Na salt was used as an anticoagulant. Plasma was quickly separated by centrifugation and stored at −20°C until assayed.

Subjects were fed the recommended diet (NaCl, 7 g/day) and allowed ad libitum water intake.

Assays of Plasma ANP, cGMP, and Catecholamines

Plasma concentrations of ANP were determined by a specific and sensitive radioimmunoassay after separation of ANP from plasma by means of affinity chromatography on anti-ANP-coupled agarose. The details of the radioimmunoassay have been described previously. The recovery of ANP from plasma was 80.7 ± 1.0(SEM)% (n = 37), and the sensitivity of the assay was 12.5 pg/ml. The coefficients of variation averaged 7.2% for intra-assay error and 11.1% for interassay error. Atenolol or acebutolol in an amount up to 5 µg did not significantly displace 123I-labeled ANP in the present radioimmunoassay system.

Plasma concentrations of cGMP were measured using a commercial kit (Yamasa Shoyu, Choshi, Japan). The sensitivity of the assay was 1.25 pmol/ml. The coefficients of variation averaged 3.9% for intra-assay error and 11.9% for interassay error. Plasma levels of catecholamines were measured by a high performance liquid chromatograph equipped with an electrochemical detector. The sensitivities of the assay were 5 pg/ml for epinephrine, 5 pg/ml for norepinephrine, and 60 pg/ml for total dopamine. The coefficients of variation averaged 1.6% (epinephrine), 1.2% (norepinephrine), and 2.4% (total dopamine) for intra-assay errors, and 4.8%, 4.2%, and 1.7%, respectively, for interassay errors.

Statistical Analyses

The significance of difference was calculated by Student's t test for paired and unpaired data. For multiple comparisons, Bonferroni's correction was used. Regression lines were obtained by the method of least squares. In patients undergoing long-term treatment with β-blockers, multivariate regression analysis was performed on plasma ANP concentrations, patient characteristics (age and pretreatment and posttreatment mean blood pressure), and plasma levels of cGMP and catecholamines (epinephrine, norepinephrine, and total dopamine).

Results

Figure 1 shows plasma ANP levels in relation to age in control subjects, in untreated EH subjects, and in EH patients undergoing long-term treatment with β-blockers. Some subjects with untreated EH had higher plasma ANP levels than did normotensive controls; however, the mean plasma ANP concentration (39.8 ± 15.8 [SD] pg/ml) was not statistically different from that in normotensive controls (33.9 ± 16.6 pg/ml). On the other hand, the mean plasma ANP concentration in patients receiving β-blockers (72.0 ± 36.0 pg/ml) was significantly higher than that in untreated EH subjects (p < 0.01) or normotensive controls (p < 0.01). When plasma ANP levels were compared with ages of subjects in each group, a significant positive correlation was observed in all three groups (see Figure 1). The slope of the regression line in patients receiving β-blockers was significantly (p < 0.01) greater than that in normotensive controls.

Figure 2 shows changes in plasma ANP levels in 10 untreated EH subjects after the administration of atenolol, 50 mg/day, for 4 weeks. In 9 of 10 subjects, plasma ANP levels rose after the treatment. The mean plasma ANP concentration after the treatment was significantly higher than that in the control period (68.7 ± 20.6 vs 38.8 ± 9.5 pg/ml; p < 0.001).
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Table 2 shows the result of multivariate regression analysis in patients taking β-blockers. Age and pretreatment mean blood pressure were found to be independent and significant predictors of plasma ANP levels (see Figure 1; Figure 3). Significant positive correlations also were observed between plasma ANP and cGMP levels and between plasma cGMP and total dopamine levels (see Figure 3).

Discussion

The present study shows that plasma ANP levels in EH patients undergoing long-term treatment with β-blockers are higher than those in untreated EH subjects and in normotensive controls. Moreover, the administration of atenolol for 4 weeks increased plasma ANP levels in untreated EH subjects. The results indicate that β-adrenergic receptor blockade elevates plasma ANP levels in EH patients. ANP is known to facilitate cGMP accumulation in various tissues, including vascular endothelial and smooth muscle cells. The significant positive correlation between plasma ANP and cGMP levels observed in the present study may indicate that increased ANP in plasma, induced by β-adrenergic receptor blockade, stimulated cGMP production. A close relationship between plasma ANP and cGMP levels has been shown under various experimental conditions.

Several factors should be considered in explaining the observed effect of β-blockers. The major action of β-blockers on the circulatory system is a reduction in...
Figure 3. Correlations between plasma ANP levels and pretreatment mean blood pressure (BP; A), between plasma ANP and cGMP levels (B), and between plasma cGMP and total dopamine (DA) levels (C). Correlation coefficient and significance values denote results of multivariate regression analysis (see Table 2). Regression lines were obtained by linear regression analysis. A correlation between plasma ANP levels and age is shown in Figure 1.

Heart rate and cardiac output. The effect of β-blockers on plasma ANP levels was present after β-adrenergic receptor blockade in elderly patients. Increased plasma ANP levels after β-adrenergic receptor blockade may represent a compensatory mechanism that operates in response to relative cardiovascular volume expansion. The significant positive correlation between plasma ANP levels and pretreatment mean blood pressure may indicate that elevation of plasma ANP levels after treatment with β-blockers depends on the severity of hypertension. The significant positive correlation between plasma ANP levels after /β-blocker therapy. However, this possibility appears unlikely, since the main cause of the elevated plasma ANP levels in patients with chronic renal failure is increased ANP secretion due to volume expansion rather than decreased ANP clearance. Thus, increased plasma ANP levels after β-adrenergic receptor blockade may represent a compensatory mechanism that operates in response to relative cardiovascular volume expansion. The significant positive correlation between plasma ANP levels and age is shown in Figure 1.

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